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Management of Burn Wounds in the Emergency Department

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In the United States, more than 1 million patients per year sustain burn injuries [1]. Of these, approximately 700,000 seek care in an emergency department, and approximately 45,000 are hospitalized. One half of these admissions are received by the approximately 125 specialized burn centers; the other one half are admitted to other hospitals. Thus, only approximately 4.5% of burn patients actually are hospitalized. The majority of patients who have burns are seen by emergency medicine providers. Accordingly, this article provides guidance for the triage of burn victims and an approach to the treatment of patients who have major burns in the first several hours after injury. There are some general remarks with respect to special injuries, such as electrical and chemical injuries. Finally, outpatient treatment of patients who have minor burns is described.

Pathophysiology of the burn wound

To understand burn wounds better, some basic facts about the skin should be reviewed [2,3]. The skin is a laminar structure. The outer layer or epidermis arises from the stratum germinativum. As cells from this layer migrate upward, they differentiate into keratinocytes that finally desquamate. The dermal layer contains epidermal appendages: hair follicles, sweat glands, and sebaceous glands. Blood vessels, nerve endings, immunocytes, fibroblasts, and elastin and collagen fibers also reside in the dermis. The subcutaneous layer is deep to the dermis. With these anatomic landmarks

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as reference points, the classification of burns based on depth of injury becomes more intelligible.

Thermal injury may be conceived as producing three concentric volumes of tissue damage (Fig. 1) [4]. The volume injured most severely, in the center of the wound, is the zone of coagulation. Outside the zone of coagulation is the zone of stasis. Beyond the zone of stasis lies the zone of hyperemia. In theory, the zone of coagulation is destroyed permanently; the zone of stasis is ischemic but potentially salvageable; and the zone of hyperemia features increased blood flow resulting from inflammation. In practice, attentive wound care and careful fluid resuscitation may salvage the zone of stasis and prevent a superficial injury from becoming full thickness.

Depth of burn and burn size

Depth of injury depends on the temperature and heat capacity of the causative agent, the duration of exposure, and the thickness of the skin. For example, hot grease, a substance with a high heat capacity, is likely to cause deep burns. Gasoline flame burns usually are full thickness, reflecting the high temperature. Patients who have underdeveloped skin, such as children, and patients who have atrophic skin, such as the elderly, are more likely to sustain full-thickness injuries than are young adults.

Determining the depth of burns on initial presentation may prove difficult even for experienced burn specialists (Fig. 2, Table 1). A burn that remains confined to the epidermis is termed a first-degree burn. An example of this is a nonblistering sunburn. Such burns rarely are of immediate medical consequence, heal rapidly, and are not included in burn size estimations for the

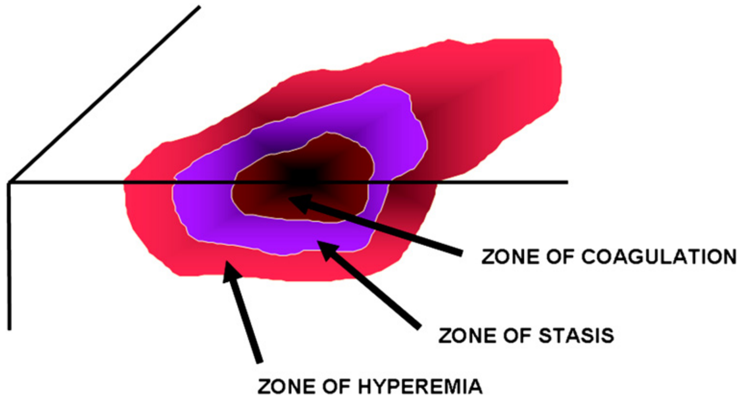

Fig. 1. Zones of injury. Thermal energy can be visualized as producing three concentric spheres of injury. The innermost is the zone of coagulation, the middle sphere is the zone of stasis, and the outermost is the zone of hyperemia.

Table 1
Classification of burn depth

	First-degree	Second-degree	Third-degree
Cause	Sun, hot liquids, brief flash burns	Hot liquids, flash or flame	Flame, prolonged contact with hot liquid or hot object, electricity, chemical
Color	Pink or red	Pink or mottled red	Dark brown, charred, translucent with visible thrombosed veins, pearly white
Surface	Dry	Moist, weeping, blisters	Dry and inelastic
Sensation	Painful	Very painful	Anesthetic
Depth	Epidermis	Epidermis and portions of the dermis	Epidermis, dermis, and possibly deep structures
Time to healing[a]	A few days	One or more weeks	(Heals by contraction)

[a] In the absence of excision and grafting.

Data from Sabiston DC Jr, editor. Textbook of surgery. 15th edition. Philadelphia: WB Saunders; 1997.

purpose of determining fluid resuscitation requirements. They may, however, be of legal significance. A burn that extends into the dermis is termed a second-degree or partial-thickness burn. Blistering scald burns are a common example. If only the superficial layer of the dermis is involved, it is termed a superficial partial-thickness burn. These burns heal in less than approximately 21 days and generally do not require skin grafting. Deeper involvement in dermis classifies the burn as a deep partial-thickness burn. These burns heal by re-epithelialization after more than 21 days and generally benefit from skin grafting. A burn involving the entire depth of the dermis and the epidermal appendages is termed a third-degree or full-thickness burn. These burns heal only by contraction from the edges, if at all, over a prolonged period of time. Thus, skin grafting is required. Because the nerve endings are found at the dermal level, the depth of an anesthetic burn is deeper than the depth of a sensate burn. Likewise, lack of blanching in a burn implies injury to the dermal blood vessels. Technologies to estimate burn depth have been developed [5], but these methods have not found widespread use in the clinical arena.

Estimation of the total body surface area burned (TBSA) as a percentage of the body surface area can be done using the rule of nines (Fig. 3) and refined with a Lund-Browder or Berkow chart [6] correlating the percentage of TBSA of different regions of the body as a function of developmental age (Table 2). Most emergency departments and burn units have one of these body surface charts available for use. Another useful rule is the rule of hands, whereby the patient's hand (palm and fingers) comprises approximately 1 percent of his body surface area. This facilitates estimation of the size of irregularly shaped burns. Careful estimation of TBSA is essential

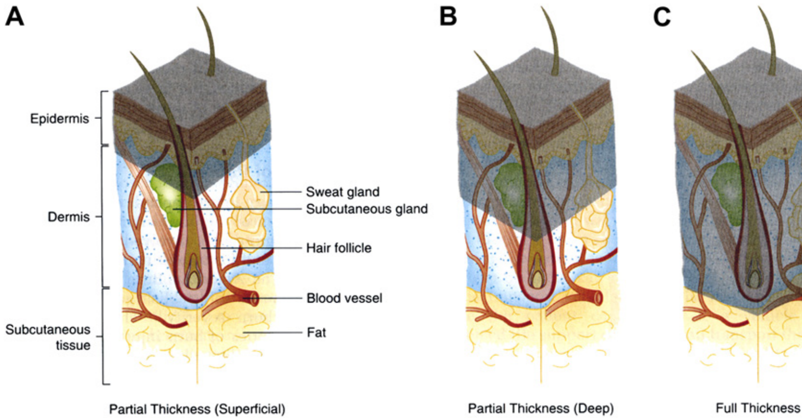

Fig. 2. Classification of burn wounds based on depth of injury. First-degree burns, limited to the epidermis, are not shown. Second-degree or partial-thickness burns commonly are divided into superficial and deep partial-thickness burns, based on healing time. Third-degree burns also are referred to as full-thickness burns. (*From* Edlich RF, Martin ML, Long WB. Thermal burns. In: Marx J, Hockberger R, Walls R, editors. Rosen's emergency medicine: concepts and clinical practice. 6th edition. St. Louis: Mosby; 2006; with permission.)

in the early management of burn patients, because burn size determines fluid requirements and triage and transfer criteria. Overestimation of the burn size by referring hospitals is common and may result from overzealous application of the rule of nines.

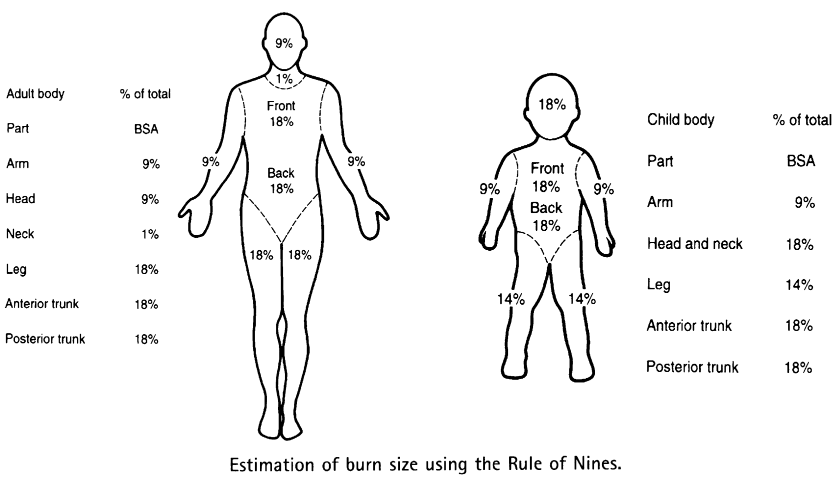

Fig. 3. The rule of nines. Areas of the body are partitioned into areas, each of which constitutes 9% of the TBSA or a multiple thereof. The exception is the genital/perineal area, which is allotted 1%. (*Reprinted from* Herndon DN, editor. Total burn care. 2nd edition. London: Saunders; 2002; with permission.)

Table 2
An example of a Berkow chart

Body part	0–1 year	1–4 years	5–9 years	10–14 years	15–18 years	Adult
Head	19	17	13	11	9	7
Neck	2	2	2	2	2	2
Anterior trunk	13	13	13	13	13	13
Posterior trunk	13	13	13	13	13	13
Right buttock	2.5	2.5	2.5	2.5	2.5	2.5
Left buttock	2.5	2.5	2.5	2.5	2.5	2.5
Genitalia	1	1	1	1	1	1
Right upper arm	4	4	4	4	4	4
Left upper arm	4	4	4	4	4	4
Right lower arm	3	3	3	3	3	3
Left lower arm	3	3	3	3	3	3
Right hand	2.5	2.5	2.5	2.5	2.5	2.5
Left hand	2.5	2.5	2.5	2.5	2.5	2.5
Right thigh	5.5	6.5	8	8.5	9	9.5
Left thigh	5.5	6.5	8	8.5	9	9.5
Right leg	5	5	5.5	6	6.5	7
Left leg	5	5	5.5	6	6.5	7
Right foot	3.5	3.5	3.5	3.5	3.5	3.5
Left foot	3.5	3.5	3.5	3.5	3.5	3.5

Estimates for each body part made and then summed to provide an accurate estimate of the TBSA.

Data from Townsend CM, Beauchamp DR, Evers BM, et al. Sabiston textbook of surgery: the biological basis of modern surgical practice. Philadelphia: Elsevier Saunders; 2004. Available at: http://home.medconsult.com/. Accessed September 2006.

Triage and treatment

What constitutes a major burn? The American Burn Association has written criteria for burn center referral (Box 1) [7]. Burn center referral does not necessarily imply burn center admission. Often, the referral should be made because the anatomic location of the burn requires evaluation by an experienced burn doctor. Some patients who require burn center referral, however, have burns severe enough to require immediate attention in an emergency department and probable admission to a burn ICU. Patients in this category include those patients who have inhalation injury, burns of more than 10% to 20% TBSA, high-voltage electrical injury, or extensive chemical injury.

Some burn patients also have associated nonthermal injuries. These patients should be approached diagnostically and therapeutically as nonthermal trauma victims with an initial evaluation, as in the American College of Surgeons Advanced Trauma Life Support algorithm [8]. Depending on severity of injury, the nonthermal injuries may take precedence over thermal injuries. If patients do not have serious nonthermal injuries, the decision should be made for burn center referral.

Patients who have burns of more than 20% TBSA commonly require intravenous fluid resuscitation [9]. The commonly used formulas predict

Box 1. Burn unit referral criteria

A burn unit may treat adults or children or both.
Burn injuries that should be referred to a burn unit include the following:

1. Partial-thickness burns greater than 10% TBSA
2. Burns that involve the face, hands, feet, genitalia, perineum, or major joints
3. Third-degree burns in any age group
4. Electrical burns, including lightning injury
5. Chemical burns
6. Inhalation injury
7. Burn injury in patients who have pre-existing medical disorders that could complicate management, prolong recovery, or affect mortality
8. Burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality. In such cases, if the trauma poses the greater immediate risk, patients may be stabilized initially in a trauma center before being transferred to a burn unit. Physician judgment is necessary in such situations and should be in concert with the regional medical control plan and triage protocols.
9. Burns in children who are in hospitals without qualified personnel or equipment for the care of children
10. Burn injury in patients who require special social, emotional, or long-term rehabilitative intervention

Excerpted from American College of Surgeons Committee on Trauma. Guidelines for the operations of burn units. Resources for optimal care of the injured patient. Chicago (IL): American College of Surgeons; 1999. p. 55–62.

a total fluid intake of 2 to 4 mL/kg/TBSA for the first 24 hours post burn (3–4 mL/kg/TBSA for children), with half of this total volume programmed for delivery over the first 8 hours post burn and half over the second 16 hours post burn. Lactated Ringer's solution is used commonly. The most important point is to then adjust the fluid rate based on physiologic response, mainly the urine output. Enough fluid should be given to maintain a urine output of 30 to 50 mL/hour in adults and approximately 1 mL/kg/hour in children weighing less than 30 kg—but no more. (The target urine output for children varies by age: 0.5–1 mL/kg/h for patients older than 2 years of age and 1–2 mL/kg/h for children under 2 years of age.) Children also require additional 5% dextrose in one-half normal saline at a maintenance rate.

Fluids actually infused often are in excess of formula predictions, in many cases because of failure to decrease fluid intake when the urine output increases. This exposes patients to the potentially disastrous risks of over-resuscitation, such as extremity and abdominal compartment syndromes [10]. The intravenous fluid rate should be changed, using urine output as the endpoint, by 20% to 30% every 1 or 2 hours. The patient also should have a clear sensorium, warm and well-perfused skin, and a heart rate of not more than approximately 120 per minute in adults. Blood pressure is not an established fluid resuscitation endpoint, but low blood pressure (mean arterial pressure $<$ 60 mm Hg) may indicate hypovolemia. Careful documentation of fluid input and output, beginning in the emergency department, is vitally important in the management of burn resuscitation. A burn flow sheet, such as that provided in Fig. 4, assists in this process.

Deep partial-thickness to full-thickness burns cause damage to the dermal layer of the skin, which contains elastin and collagen fibrils and provides elasticity to the skin. If such a burn encompasses a limb, the inelastic burned skin (eschar) and the burn edema fluid that builds up beneath it act like a tourniquet, compressing the vascular supply and compromising nerve function. These types of burns require frequent and vigilant assessment of peripheral pulses, skin perfusion, and neurologic function. Edema should be reduced by elevating the extremity above the level of the heart. Many such patients require escharotomies, however, to relieve the tourniquet-like circumferential burn. If the burn occurs on the thorax or upper abdomen, the eschar likewise can compromise respiratory excursions; this situation also requires an escharotomy. An escharotomy usually is performed by a burn specialist or surgical consultant.

Other important caveats in the treatment of major burn patients in the immediate hours after injury include the following: keep the patient warm, do not apply wet linens, do not apply ice, and do not cool the patient. There is no need to apply topical antimicrobials before transfer to a burn center, provided transfer can be accomplished within 24 hours. Remove all jewelry and rings to protect limbs, hands, and digits. Prophylactic antibiotics are not indicated in burn injuries [11]. Do not use oral, intravenous, or topical steroids [12]. Use frequent, small doses of intravenous narcotics for pain management.

Special burns

Burn center referral is advised for patients who have electrical injuries. Patients who have high-voltage electrical injuries (contact with $>$ 1000 V) are at elevated risk of spinal injury and require complete immobilization until this is ruled out. Direct muscle damage may cause gross myoglobinuria, requiring more aggressive fluid resuscitation [13]. In the presence of gross myoglobinuria, fluids should be administered at a rate sufficient to produce a urine output of 75 to 100 mL/hour in adults. If this does not produce

JTTS Burn Resuscitation Flow Sheet **Page 1**

Date: | **Initial Treatment Facility:**

Name	SSN	Pre-burn Est. Wt (kg)	%TBSA	1st 8 hrs	2nd 16th hr	Est. Total 24 hrs

(Estimated fluid vol. pat. should receive: 1st 8 hrs, 2nd 16th hr, Est. Total 24 hrs)

Date & Time of Inury BAMC/ISR Burn Team DSN 312-429-2876

Tx Site/ Team	HR from burn	Local Time	Crystalloid / Colloid	TOTAL	UOP	Basez	BP	MAP (>55) / CVP	Pressors (Vasopressin 0.04 u/min)
	1st								
	2nd								
	3rd								
	4th								
	5th								
	6th								
	7th								
	8th								
	Total Fluids:								
	9th								
	10th								
	11th								
	12th								
	13th								
	14th								
	15th								
	16th								
	17th								
	18th								
	19th								
	20th								
	21st								
	22nd								
	23rd								
	24th								
	Total Fluids:								

Fig. 4. Burn fluid resuscitation flow sheet. This flow sheet was developed for use during the current conflict in Iraq and Afghanistan but is equally useful in civilian practice. MAP, mean arterial pressure; UOP, urine output.

gradual clearing of the urine over, for example, 3 hours, mannitol (25 g) should be given every 6 hours (and central monitoring should be considered). In addition, an infusion of sodium bicarbonate (150 m EQ/L) may be used to alkalinize the urine and reduce tubular pigment deposition. Gross myoglobinuria is an indication of severe muscle damage; these patients often require urgent fasciotomy in the operating room [14]. A severely injured

electrical injury patient usually requires ICU care for resuscitation and monitoring. In severe electrical injuries, cardiac dysrhythmias are not uncommon; almost any type of dysrhythmia may be seen [15].

Chemical burns are another indication for burn center referral. One of the most important points in treating patients who have a chemical injury is protection of the treating team from the chemical that caused the injury to the patients [16]. The other important point is to irrigate the patients copiously with water, beginning at the scene and en route. If the chemical is in a powder form, it should be brushed off before irrigation is begun. For ocular irrigations, Morgan lenses and 0.9 normal saline solution should be used for irrigation.

Patients who have inhalation injury also should be referred to a burn center. Such patients constitute 10% to 20% of burn center admissions. Patients who have isolated inhalation injury (without cutaneous burns) may have an obscure or perplexing presentation [17]. On examination, singed nasal, facial, or scalp hairs, intraoral mucosal edema or blisters, or changes in the character of the voice may suggest but are not specific for inhalation injury. Inhalation injury is more common in patients who have large burns, are at the extremes of ages, who have facial burns, and who were injured in enclosed spaces [18]. The severity of inhalation injury cannot be judged on outward physical findings [19]. Fiberoptic bronchoscopy enables assessment of airway patency, permits the diagnosis of subglottic injury, and may facilitate endotracheal intubation. It is important to obtain carboxyhemoglobin levels in patients who have inhalation injury and to give the patients 100% oxygen for support until the level is less than 10% [20]. Early, prophylactic endotracheal intubation is essential for patients who have suspected inhalation injury, because laryngeal edema may progress rapidly. Even patients who have large burns and do not have inhalation injury may require intubation to guard against progressive airway edema.

Outpatient burn care

Patients who have minor burns (less than 10% TBSA) make up the majority of patients who have burns seen in emergency departments. By definition, patients who have a minor burn should not need fluid resuscitation for shock. If such a patient is in shock, there should be serious concern for a missed nonthermal injury or another problem.

Not all patients who have minor burns are candidates for outpatient management of their wounds. A family support structure is required to engage in dressing changes, to participate in range-of-motion exercises, and to transport patients for outpatient appointments and occupational and physical therapy visits.

Steps in the outpatient management of burns include the following:

- Even for minor burns, tetanus immunization status should be evaluated and brought up to date as needed [21].

- Provide adequate analgesia. For initial débridement, a narcotic, such as fentanyl or morphine, commonly is used. Some patients may require conscious sedation (eg, with ketamine). For home care, consider nonsteroidal anti-inflammatory drugs for background pain and an oral narcotic for dressing changes.
- Clean the burn with a mild surgical detergent, such as chlorhexidene gluconate [22].
- Débride dead skin with moist gauze or by sharp dissection with scissors and forceps. In general, blisters in excess of 2 cm diameter should be unroofed [23].
- Apply a dressing (discussed later).
- Ensure that patients are re-evaluated within 24 hours in a burn center, clinic, or other venue where the wound can be re-evaluated for progression and where patient compliance with instructions can be assessed.
- A mechanism should be in place allowing patients access to care for untoward events, such as wound infections.

Topical antimicrobials with efficacy against gram-negative organisms, such as mafenide acetate and silver sulfadiazine, are shown to exert a significant impact on postburn survival, particularly in patients who have large burns [24]. For small burns, the choice of topical agent is less important. Moist dressings are superior to dry dressings, however, in that moisture fosters re-epitheliazation of a wound [25]. For outpatient purposes, commonly used topical antimicrobials include silver sulfadiazine cream, bacitracin, and neomycin. For these, a coat of the substance is applied to the débrided burn wound; a nonadherent material, such as Adaptic (Johnson & Johnson, New Brunswick, New Jersey) is placed over the cream, and a gauze dressing is placed over this. The dressing can be held in place with an elastic dressing, such as an ACE bandage (BD, Franklin Lakes, New Jersey). For areas that have irregular contours, burns can be treated in open fashion. This means that the cream is applied to a burn, but no gauze is applied. Patients then must be instructed to reapply the cream as frequently as needed.

Silver ion is the active component in silver sulfadiazine and recently has been impregnated into dressings [26]. Available formulations include Silverlon (Argentum Medical, Libertyville, Illinois) and Acticoat (Smith & Nephew, Fort Saskatchewan, Alberta, Canada). These dressings may be left in place for several days, facilitating outpatient care.

Biobrane (Berkek Pharmaceuticals, Morgantown, West Virginia) is a dressing without active antimicrobial properties but that works well for superficial partial-thickness burns. This is a bilaminar material with an outer layer of silicone and an inner layer of collagen-impregenanted nylon mesh that lies against the burn wound. The inner layer acts as a scaffolding for reepitheliazation of the burn wound bed. The dressing reduces pain and promotes healing. Typically, this dressing is applied in an emergency department; the patient is instructed to leave the dressing in place and to return for

a follow-up office visit in approximately 2 days for inspection. The Biobrane separates as the burn heals. If the burn wound is deeper than superficial partial thickness, purulent material may accumulate under the dressing. If this occurs, the Biobrane should be removed where it overlies the purulent collection, and the wound should be treated as deep partial or full thickness in depth.

Average laypersons require some training in products, such as Biobrane, Silverlon, and Acticoat. In addition, these dressings should not be used on patients who are not likely to return for follow-up visits.

Summary

- Evaluate patients for nonthermal injuries.
- Triage patients by severity of injury, based primarily on burn size and the presence of inhalation injury.
- Accurate estimation of the burn size is crucial in early management decisions.
- The selection of the fluid resuscitation protocol is less important than the execution of the protocol and the assessment of patients during the process, in order to avoid over-resuscitation.
- Patients who have electrical, chemical, or inhalation injuries also merit burn center referral.
- High-voltage electrical injuries often produce more damage than is apparent by inspection; gross myoglobinuria mandates more aggressive resuscitation and, possibly, urgent fasciotomy.
- Protection of health care personnel and early decontamination is paramount in treating patients who have chemical injuries.
- Early prophylactic endotracheal intubation of patients who have inhalation injury or large burns prevents airway obstruction during resuscitation.
- Selection of patients who may be treated as outpatient burn patients hinges as much on social issues as on medical concerns.

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